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Modulation of Low-Energy Galactic Cosmic-Ray Hydrogen and Helium

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A study of the energy spectrum of the cosmic-ray hydrogen and helium nuclei as a function of the period in the solar cycle provides one of the better means of gaining insight into the mechanism that modulates the galactic cosmic radiation. An examination of these nuclei in the low-energy region, where the modulation effects are greatest, has the particular merit of permitting the separation of velocity and rigidity effects, since for a given rigidity the helium nuclei have a markedly different velocity from that of the protons. Considerable information related to this problem had been obtained before 1960 for the most recent period of increasing solar activity [*Webber*, 1962].

In order to continue the study of the problem of the variation of the galactic cosmic-ray proton and helium nuclei spectrums and extend it to lower energies, a series of balloon flights, beginning in 1961, has been made from Fort Churchill, Canada. It is the aim of this letter to present the results of the nuclear emulsion studies of the hydrogen and helium nuclei obtained in 1962 and 1963 and compare them to those obtained in 1961 [*Fichtel et al.*, 1964].

The experimental data were obtained by carrying sets of nuclear emulsions aboard high-altitude skyhook balloons flown from Fort Churchill, Canada, where the earth's magnetic field allows all particles in the rigidity interval being studied to reach the top of the atmosphere. A second nuclear emulsion stack is released at the time the primary stack is rotated into the exposure position. The second stack provides the necessary information on the background particles collected during ascent and descent which must be subtracted from the particle flux measured in the primary stack, since nuclear emulsions are an integrating device.

There is not space here to describe in detail the corrections which must be applied to the data, but the discussion of the method along with self-consistency arguments has been given in some detail in an earlier paper [*Fichtel et al.*, 1964] and will be treated further in the final publication of this work. It is appropriate to mention, however, that there is a substantial secondary proton flux from interactions in the atmosphere above the detector, and allowance has been made for the uncertainty in the interaction correction in the calculation of the errors associated with the flux values that are quoted below.

In earlier work during the years 1955 through 1960, McDonald and Webber had shown that higher-energy data at higher-rigidity geomagnetic cutoffs suggested that the proton rigidity spectrum was the same as that for helium multiplied by seven [*Webber*, 1962]. Figure 1 shows that in the present data there is a general tendency for the proton points to lie above a reasonable extension of a smooth curve through the helium nuclei data multiplied by seven both in 1961 and 1962. In Figure 2 the 1963 proton data from the nuclear emulsions are plotted together with the proton and helium data of *Balasubrahmanyan and McDonald* [1964] at higher rigidity. Their data were obtained from counter experiments flown on June 24, 1963, when the high-latitude neutron monitor readings differed from those on June 15 and 16, 1963, when the emulsions were flown, by much less than 1 per cent. In Figure 2 the splitting between the rigidity spectrums of the two components is quite marked. Hence, these results suggest strongly that there is a splitting below about 1.3 bv between the proton differential spectrum and that for helium nuclei multiplied by seven. This conclusion is not inconsistent with the earlier statements [*Fichtel et al.*, 1964] about the agreement in the rigidity spectrums of the proton and helium components during

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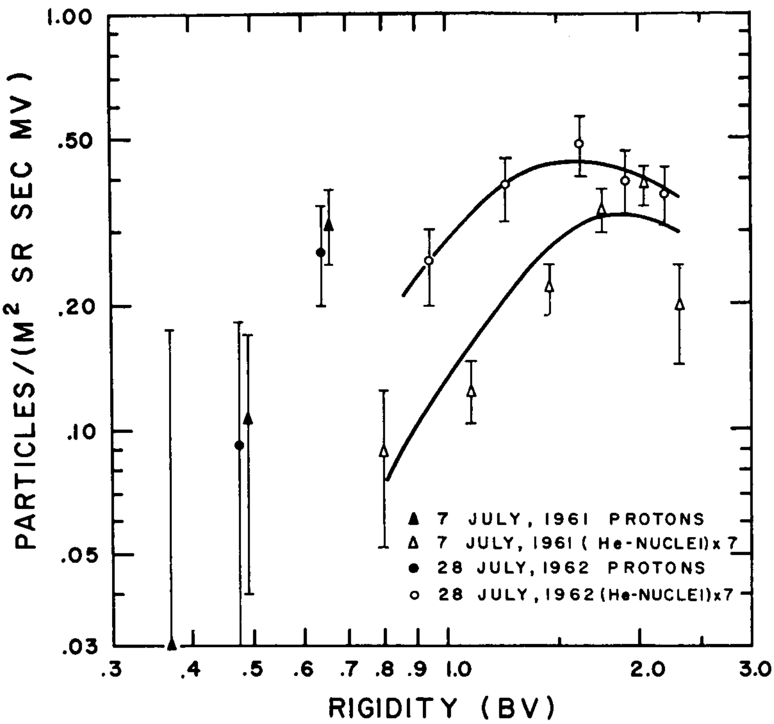

Fig. 1. Proton and He nuclei differential rigidity spectrums from 1961 and 1962 balloon flights at Fort Churchill.

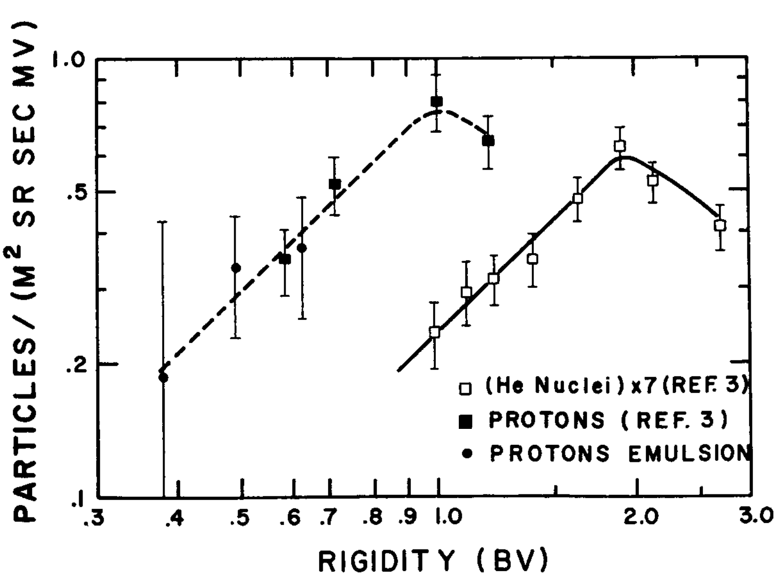

Fig. 2. Proton and He nuclei differential rigidity spectrums from 1963 balloon flight from Fort Churchill.

the declining phase of cosmic rays because there is not sufficient helium data below 1.3 bv during the earlier period to justify a comparison in the 0.4- to 1.3-bv rigidity region.

Although there is the problem of not knowing the particle spectrum outside the solar system, the splitting effect for the galactic spectrums normally suggested is at least qualitatively in agreement with the prediction of the modulation mechanisms currently proposed. Most of these models predict that protons will be less suppressed because they have a higher velocity for a given rigidity than helium nuclei. Therefore, unless the proton rigidity spectrum is very different from the helium spectrum in free space, the type of splitting in the spectrum which is observed would be predicted by these models. A more complete discussion of modulation models can be found elsewhere [*Webber*, 1962; *Fichtel et al.*, 1964].

References

Balasubrahmanyan, V. K., and F. B. McDonald, Solar modulation effects on the primary cosmic radiation near solar minimum, *J. Geophys. Res.*, *69*(15), August 1, 1964.

Fichtel, C. E., D. E. Guss, G. R. Stevenson, and C. J. Waddington, Cosmic ray hydrogen and helium nuclei during a quiet time in 1961, *Phys. Rev.*, *133*, B818, 1964.

Webber, W. R., *Prog. Elem. Particle Cosmic Ray Phys.*, *6*, 1962 (see particularly Figure 31*a*).

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